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Study of Large Wind Power Generator with Evaporative Cooling System

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Abstract – **Evaporative cooling system has the advantage of high cooling performance, good insulation properties, less electrical fault, easy to maintain and high reliability, can meet the requirements of the cooling system in wind power generators. Based on a large number of theoretical researches and engineering practices, we had a comprehensive study of evaporative cooling wind power generator. Studies show that evaporative cooling system has advantage as the cooling system of wind power generator**

Keywords: Wind Power Generator, Evaporative Cooling, Easy maintain, High reliability

1. Introduction

With the large-scale development of wind turbines, the generator cooling problems loom large. Conditioned by their own disadvantages traditional cooling system like wind cooling system and water cooling system are difficult to meet the requirements of the cooling system. Evaporative cooling system has the advantage of high cooling performance, good insulation properties, less electrical fault, easy to maintain and high reliability, can meet the requirements of the cooling system in wind power generator [1], [3].

Evaporative cooling technology research and development center, Institute of Electrical Engineering, Chinese Academy of Science, has carried out a lot of basic theory research and engineering practice for evaporative cooling technology in the application of the wind turbines. We will conduct a detailed description and summary of these works in this paper to providing a reference for the further development of evaporative cooling wind turbines.

2. Evaporative Cooling System

1.1 Immersion Evaporative Cooling System

Immersion evaporative cooling system is shown in Fig. 1, the generator stator core and stator winding is placed in a sealed sleeve, cooling medium is poured into the sleeve and the stator core and stator winding is immersed by the cooling medium.

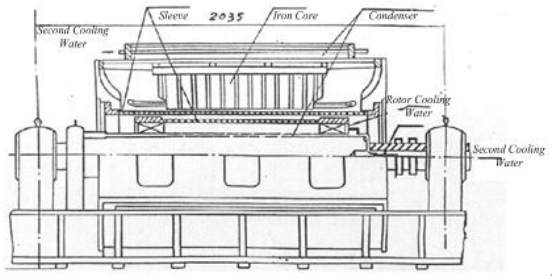

Fig. 1. Immersion evaporative cooling system

1.2 Inner Evaporative Cooling System

We use hollow conductors in stator windings of generators with inner evaporative cooling system. Cooling medium flows through the hollow conductors and taking away heat. This technology has been successfully used in hydroelectric generators. The most typical example is the 28th units of the Three Gorges underground power station (as shown in Fig. 2).

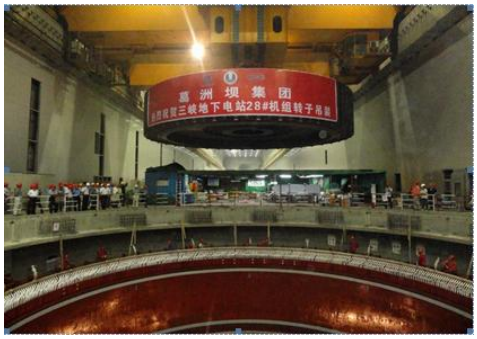

Fig. 2. 28th inner evaporative cooling units of the Three Gorges underground power station

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Work principle sketch of the inner evaporative cooling system is as shown in Fig. 3 [1], [5], [6].

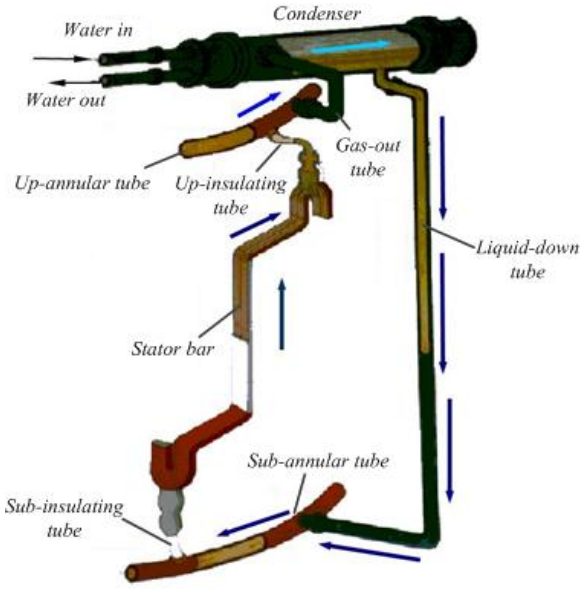

Fig. 3. Inner evaporative cooling system

It works as follows: the stator bar emits heat when the generator is in the running and the cooling medium in the hollow conductor of the stator bar absorbs heat and then evaporates, the heat is taken away by the latent heat of vaporization. Gaseous medium flows up into the condenser through the up-annular tube and cooled by the condenser, then deliquesces and follows down through the liquid-down tube, beginning the next cycle.

3. Study of Wind Driven Generators with Evaporative Cooling System

Wind power generators in the running are generally cooled by forced air cooling system and water cooling system. Forced air cooling system has a simple structure, low initial investment and operating costs, more convenient for management and maintenance. However, its cooling effect greatly affected by air temperature, cooling efficiency is low and the temperature distribution is uneven. Water cooling system is more compact compared with forced cooling system, but its flow channel is easily blocked. Moreover, joints and seal points in the flow channel would leak because of the high water pressure (0.3~0.6MPa), causing a short circuit.

Compared with forced air cooling system and water cooling system, evaporative cooling system has several advantages as follows:

(1) High cooling performance and uniform temperature distribution, increasing the power density;

(2) Good insulation performance and high security;

(3) Self-circulation needs no accessory equipment and easy to maintain;

(4) Use the natural wind for recooling and make full use of the natural energy.

Evaporative cooling system has been successfully applied to large-scale hydro-generator and large steam turbine generator. We also developed a number of evaporative cooling wind turbines and dive them into network operation.

3.1 Wind Power Generator with Immersion Evaporative Cooling System

Immersion evaporative cooling technology is suitable for the doubly-fed wind generator and half-direct driven wind generator [2].

As shown in Fig. 1 is the immersion evaporative cooling system, in which sleeve is placed in the air-gap between the stator and rotor to form a sealed space. We pour the cooling medium into sleeve so that the stator is fully immersed. Cooling medium will evaporate when heated, and the gas medium flows into the condenser and cooled by the cooling water, then the gas medium liquids and flows back to the sleeve.

We have successfully developed a 1MW brushless doubly-fed wind power generator with immersion evaporative cooling system (Fig. 4), a 2MW direct-driven wind power generator with immersion evaporative cooling system (Fig. 5) and a 3.6MW half direct-driven wind power generator with immersion evaporative cooling system (Fig. 6). After three months of grid-connected trial operating, the 3.6MW wind power generator had successfully passed the test in September 2012 (as shown in Fig. 7).

Fig. 4. 1MW brushless doubly-fed wind power generator with immersion evaporative cooling system

Fig. 5. 2MW direct-driven wind power generator with immersion evaporative cooling system

Fig. 6. Two 3.6MW half-direct driven wind power generator with immersion evaporative cooling system in testing

Fig. 7. Grid-connected trial operating of the 3.6MW half direct-driven wind power generator with immersion evaporative cooling system

As the China 12th five-year science and technology support project "Grade 7MW wind power generator industrialization key technology research and development" is successfully set up, evaporative cooling technology will be applied in the largest capacity permanent magnet half-direct driven wind turbines during the 12th five year.

3.2. Wind Power Generator with Inner Evaporative Cooling System

In immersion evaporative cooling generator, we must have the whole stator immersed in the medium, so it needs a lot of cooling medium. This causes the high price of the generator and restricts the application of the system in wind turbines. Inner evaporative cooling system can solve this problem. It needs less cooling medium and has a cheaper price. Especially in wind power generators large than 5MW, they have larger stator space for the medium and electrical joint of inner evaporative cooling system.

As wind turbines have a 3~5 degree angle to horizontal direction, we exploit this characteristic to make the inner evaporative system achieve self-circulation. Inner evaporative cooling technology for wind turbines is now in the basic research stage, we have finished the experimental and theoretical analysis of two-phase flow frictional pressure drop and instability in the inclined rectangular hollow conductors, according to the design parameters of 2MW evaporative inner cooling wind power generator. The experimental facility is as shown in Fig. 8 and Fig. 9.

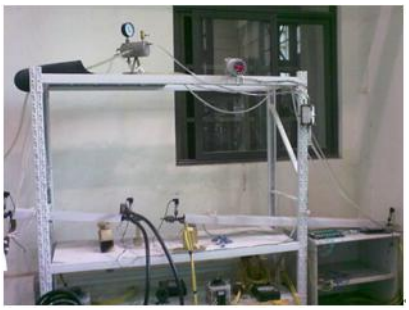

Fig. 8. Experimental facility for two-phase flow frictional pressure drop reseach in inclined rectangular hollow conductors

Fig. 9. Experimental facility for two-phase flow instability reseach in inclined rectangular hollow conductors

Moreover, the 1:1 model experimental research of stator evaporative cooling system is carrying on and we will test the thermal performance and stability of the inner cooling system by experimental and theoretical methods. Divide the generator stator into several parts, hollow conductors in every part sharing one condenser for cooling. The condensers use the natural wind for recooling and make full use of the natural energy (as shown in Fig. 10).

All these works above-mentioned will lay a solid foundation for the application of inner evaporative cooling system in wind turbine.

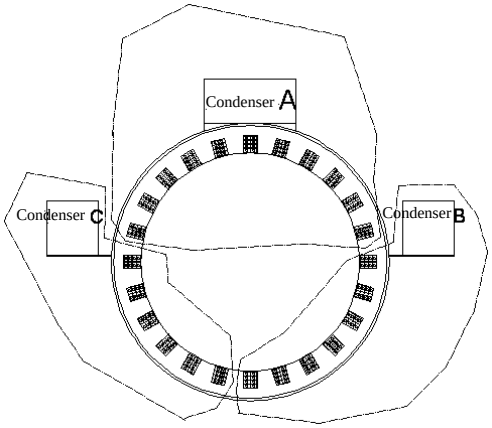

Fig. 10. Grouping evaporative cooling technology for large capacity direct-driven wind turbine

3.3. Evaporative Cooling Technology for Offshore Wind Power System

Offshore wind power system includes synchronous generator, frequency converter, main circuit breaker and line coupling transformer (as shown in Fig. 11), all of these facilities are cooled by evaporative cooling system. As the high efficiency of the evaporative cooling system, the whole system has a compact layout and saves the valuable space on the sea. Moreover, evaporative cooling has the ability of self-circulation and needs little maintenance. Therefore, it is very suitable for offshore wind power system to use evaporative cooling system.

4. Outlook

With the development of wind power, especially the development of offshore wind power, the application of evaporative cooling technology in wind market will have a rapid development. Evaporative cooling technology is expected to become the mainstream cooling technology for large-scale offshore wind power units.

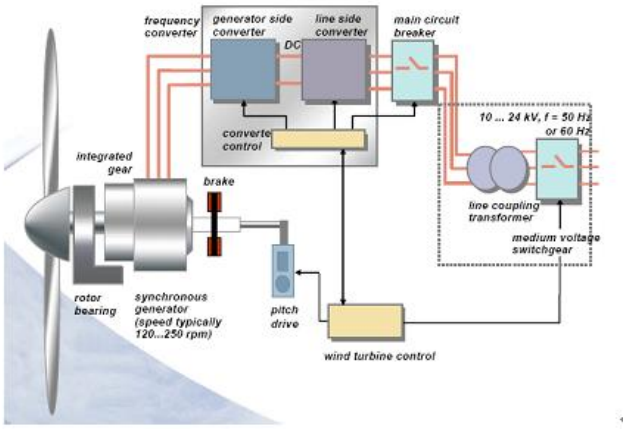

Fig. 11. Offshore wind power system

5. Conclusion

Even though the conclusion may review the main results or contributions of the paper, do not duplicate the abstract or the introduction. For the conclusion, you might elaborate on the importance of the work or suggest the potential applications and extensions.

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